

PROBLEMS OF ENSURING QUALITY OF A SURFACE LAYER WHEN PRODUCING COMPONENTS FROM HARD-TO-PROCESS HEAT RESISTANT ALLOYS

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Received: 08.06.2016

Accepted: 14.06.2016

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Abstract

We consider the study results of the hard-to-process titanium-based alloys processing on turning lathes. The influence made on the quality of the surface layer, characterized by the amplitude roughness parameters, by geometry, cutting tool properties, processing modes and dimensional wear is considered.

Keywords: aluminum alloys, superhard synthetic materials, synthetic diamond cutters, cubic boron nitride cutters

1 Introduction

The new materials producing, their improvement and application depend on the level of society development, as one cannot meet the need in new machines and devices without using new materials.

Modern enterprises of the aircraft and aerospace technology solve complex problems while designing new generations products (aiming to reduce the production and operation costs, including simplification of design and reduction of the parts and components number), requiring the materials development that would be able to function effectively under the conditions of long cyclical effect of high temperature aggressive media and their processing technologies [1].

These materials are to be heat- and erosion-resistant, they should possess high heat resistance, low density, and as well be resistant to the space environment factors effects. Today, traditional methods of new materials development have already exhausted their potential. For example, rising of the heat resistance of metal materials by increasing the alloying elements content, and of the thermochemical hardening technology has reached its limit capacity. The same can be said for ceramics. Today, traditional methods do not allow to increase resistance to thermal shocks and thermal cycling that arise in the operation of critical units of aerospace technology [2].

A large potential for enhancing constructions operational characteristics in the field of aircraft propulsion engineering is in the use of promising titanium alloys [3].

Analyzing existing research and practical solutions of machining titanium alloy raw workpieces and maraging steels in our country, we can conclude that increasing productivity and strict deadlines for the rocket and space equipment (RSE) manufacture require substantial increase in

research on the design of modern technologies of new heat-resistant alloys processing, necessary for aircraft propulsion engineering.

First of all, the designed technologies should ensure products required quality to meet their technical and economic parameters. Currently, one uses a set of parameters to estimate the quality of mechanical engineering products, these include: accuracy in dimensions and accuracy of geometric elements and texture of the surface layer, being mainly characterized by amplitude roughness parameters.

It is important to note that in the industrially developed countries there is a trend of constant stiffening of the dimension tolerances. According to the data [4], the tolerances for many machine tool operations decreased in 5 times in the period of 1940-2000. At the same time, the average upper and lower deviations, attributable to the surface roughness, increased from 15% in 1940 to 50% today. This trend leads to that the increase of roughness shares in general deviations of the dimensional tolerance dramatically toughens the requirements to geometric elements tolerances (form and position tolerances).

Such situation is also confirmed by the order No. 529 «On approval of strategy of ensuring uniformity of measurements in Russia up to 2015» of the Russian Federation Ministry of Industry and Trade, dated June 17, 2009. It notes that the requirements to the accuracy of measurements increase by 3 - 10 times every 10 - 15 years. The information, given above, shows the way how important become the requirements of ensuring the necessary quality of the surface layer, especially in high-precision components of aircraft propulsion engineering.

The height of the surfaces microasperity affects the uncertainty of the dimension of the manufactured component, as it becomes unclear between what specific points of its surface the size should be measured. With the general tendency to decrease both dimensional and components geometrical elements tolerances in mechanical engineering, the percentage composition of roughness and waviness increases in the specified tolerances [4].

The R_a roughness parameter value can reach 0.4 - 0.2 microns (that is the case for aircraft engines components) at different working surfaces [5-8].

Thus, it becomes important and necessary to conduct research on the influence of such parameters as the cutting speed, the oscillation of a technological system elements, the geometry of a cutting tool, and the other process parameters – on the value of the surface roughness numerical parameters aiming to determine the stable cutting range, in which the surface roughness parameters are of their minimal values.

A typical representative of such alloys is a titanium BT1-00 alloy. It is exactly this alloy on which the method of determining rational cutting conditions was worked out on aiming to ensure the required numerical parameters of the surface roughness. According to the recommendations [9, 10], a tool with the VCGX160404-AL H10 hard alloy base and cutting modes of $S = 0.1$ mm/rev motion and $t = 0.3$ mm depth of cut was selected. The cutting speed varied in 40-500 m/min range.

The studies were conducted on the 16V16KA universal turning lathe of high accuracy [11, 12]. Raw workpieces of a cylindrical shape were notched with a diameter of 100 - 120 mm. After processing, using a modern equipment – profile meter-recorder M400, Mahr Gmb – we measured the R_a and R_z roughness parameters.

The M400 main technical characteristics are:

- measurable parameters: complete profile, waviness and roughness;
- for measuring it uses inductive system with the 2 μm curvature radius interchangeable probes, the measuring force constitutes 0.7 μN , magnetic fastening ferrules;

- The Gaussian and Ls filters;
- M400 measures the following parameters:

R_a – is the arithmetic average of profile deviation – the arithmetic average of absolute values of the profile deviations within a base length;

R_z – is the height of profile asperity measured by ten points – the sum of the average absolute values of height of five biggest profile peaks and depths of five largest profile valleys within the base length;

R_{max} – the maximum profile height – the distance between the profile peaks and valleys lines within the base length;

S_m – is the average pitch value of the profile asperities within the base length;

S – is the average pitch value of the profile local peaks within the base length;

t_p – the relative supporting profile length – the ratio of the profile supporting length to the base length.

According to the ISO standard, additionally there are more than thirty parameters used for describing the surface texture.

The parameters were measured at different points of made components (from five to ten measure points were used), their average value was determined.

The roughness parameters dependencies on V cutting speed are given in **Fig. 1**.

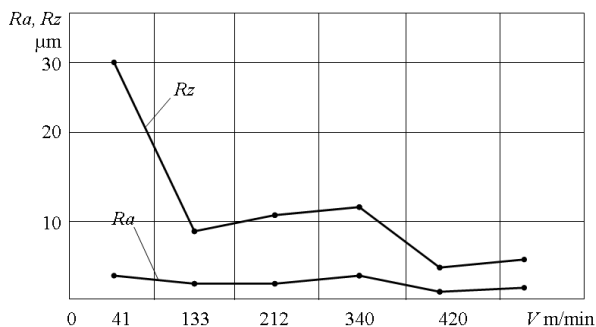


Fig. 1 The dependence of surface roughness amplitude parameters on the cutting speed while turning a titanium alloy

Fig. 1 shows that the most rational cutting speed that ensures surface roughness when turning the titanium VT1-00 alloy is about 420 m/min.

Stable cutting with a tip radius is characterized by a constant ratio between the R_a and R_z values: $R_z \approx 4 R_a$. A significant difference between the R_a and R_z parameters values occurring at low cutting speeds indicates that the surface roughness is of irregular nature, it is as well confirmed by the Figure 1. So, for example, with a 100 m/min speed parameter R_z has value 30 μm , and parameter R_a - 3,1 μm .

At cutting speeds exceeding 400 m/min, the roughness value starts increasing as there occur oscillations in the cutting zone. The oscillations are very significant when operating under cutting conditions that conduce their occurrence [13]. With the increase of speed the R_a and R_z ratio starts increasing again. There are oscillations traces clearly visible.

Cutter grinding angles and shape of a cutting tool wedge have a great influence on quality of a surface being processed. In the series of works, there are given the following recommendations

on choosing a cutting grinding angle of a cutting tool, equipped with the synthetic diamond inserts for the titanium alloys processing: $\gamma = 0 - 5^\circ$, $\alpha = \alpha_1 = 12^\circ$, $\lambda = 0$, $\varphi = 40^\circ$, $\varphi_1 = 15 - 20^\circ$, length of the transitional cutting edge (or the cutting tip radius) - 0.1 - 0.6 mm.

Grinding and polishing of cutters front and rear surfaces improve their durability in 1.5 - 2 times by reducing an adhesion intensity in the contact area between processed material and scobs, and tool surface. As well, a creation of chamfers on the rear cutter surface in the cutting plane with a width not exceeding 0.1 mm seems promising. A narrow chamfer significantly hardens the cutting wedge near its corner and, moreover, makes a smoothing effect on a surface being processed.

The work [10] gives the following recommendations concerning sharpening tools, equipped with plates of cubic boron nitride: front angle $\gamma = -5 - 10^\circ$, main rear angle $\alpha = 6 - 8^\circ$, auxiliary rear angle $\alpha_1 = 10 - 15^\circ$, plan approach angle $\varphi = 30 - 45^\circ$, plan auxiliary angle $\varphi_1 = 10 - 20^\circ$, it is recommended to do chamfer near the corner with the size of 0.2 - 0.6 mm.

Some authors [9,10] recommend machining of titanium alloys workpieces for particular operations using a cutting tool with inserted cubic boron nitride and synthetic diamonds with the following cutter grinding angles: $\gamma = -6 - 0^\circ$, $\alpha = 6 - 8^\circ$, $\varphi = 40^\circ$, $\varphi_1 = 15^\circ$, besides, they recommend making a radius or a chamfer near the corner of 0.1 - 0.7 mm.

2 Conclusions

Changing dimension wear of a tool, as it turned out, affects roughness of a machined surface. Before reaching a certain value of dimension wear, roughness does not change much, and after reaching increases significantly. After it, the character of a dimension wear does not change, but there appears a clearly visible chamfer on a rear edge.

Based on all mentioned above the following conclusions may be made:

The dependence of amplitude parameters of surface roughness on the cutting speed has a well-expressed minimum that corresponds to the zone of stable cutting, when there are no hardening formation and oscillations of technological system. It is recommended to conduct machining in this range of cutting speeds.

There is a big difference between the R_a and R_z values of parameters in the unstable cutting zones, and in the stable one the ratio of these parameters is minimal and remains constant. Based on this ratio, stability of the cutting process can be analyzed.

Till certain moment, dimension wear of a cutter almost does not affect values of the surface roughness parameters. The roughness increases significantly when a clearly visible chamfer appears on the back edge of the cutter. The moment of the sharp roughness deterioration can be considered as a durability limit of a tool at finish turning of non-ferrous alloys.

A sharp increase in roughness of a machined surface can serve as an indicator that a cutting tool needs to be replaced.

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